Complexity, Governance & Networks – Vol. 7, No 1 (2021) Special Issue: Complexity and Time in Governance, p. 5-14
DOI: http://dx.doi.org/10.20377/cgn-109

Process Complexity

Author: Jean Boulton

Cranfield School of Management, Cranfield University, United Kingdom; Department of Social and Policy Sciences, University of Bath, United Kingdom

Email: jboulton@claremont-mc.co.uk

We develop the ontology of "process complexity" and describe how the dynamics of "becoming" can be framed as the emerging, stabilising, and ultimate dissolving of "patterns of relationships." By extending traditional complexity thinking through introducing a "field theory" view, we develop a more nuanced and inclusive perspective of the processual complex world. We show how this leads to the idea of ontological uncertainty. We demonstrate how process complexity resonates with the ontologies of many different schools of thought including quantum gravity, the process philosophers of the Axial Age, and the early modern process philosophers impacted by Darwin's theory of evolution, such as Bergson, Whitehead, and James. The remarkable alignment of these diverse perspectives from science and philosophy adds conviction and depth to the development of process complexity. We conclude by indicating how process complexity influences our approach to policy and management practice.

Keywords: complexity; irreversibility; indeterminism; emergence; theory; ontology; process; uncertainty; processual; patterns; quantum gravity; Daoism; process philosophy; ontological uncertainty

Introduction

The focus of this paper is on the ontology of the complex world. We take as its foundation Prigogine's concern with the thermodynamics of open systems and link this to the deepening of a more processual turn in complexity thinking.

The foundations of our work in complexity theory derives from the legacy of Ilya Prigogine and Peter Allen (Boulton et al, 2015). Prigogine was a physical chemist, and his abiding interest was in the irreversible nature of time and in the seeming contradiction between the physics of thermodynamics and theories of evolution of the living world. Equilibrium thermodynamics suggests that the universe winds down and becomes less structured over time, but evolutionary theory shows how living systems tend to become more ordered, more sophisticated. Prigogine's Nobel Prize was awarded for exploring the thermodynamics of *open* systems, and showing that, locally, order can emerge out of chaos (Prigogine & Stengers, 1984). Thus, a seeming contradiction between the behaviour of natural and physical systems was resolved. Prigogine was one of the founding fathers of complexity theory and showed how the behaviour of complex situations is in part derived from the *necessity* of openness to their wider context.

This paper is primarily about ontology. The central aim is to show that the ontological stance of processual complexity, following the tradition of Prigogine, is almost indistinguishable from the ontology embedded in Daoist process philosophy, from the 5th century BCE, and, equally, resonates with the much more recent development of quantum gravity (Rovelli, 2018). We are keen to illustrate how ideas that were developed within the physical and natural sciences closely match ideas abstracted from the lived experience of social beings.

This aim to demonstrate ontological parity between ideas emerging from very different traditions may seem rather remote from the practical world of management and policy. Jackson (2019) and Morgan (1986) would argue, for example, that one can be pragmatic about selecting an ontological stance. Given that no description of "reality" is ever incontrovertibly "true" or "right" and can never describe things in their entirety, then, they would argue, it is sufficient to pick an ontological lens or image that seems helpful and "works" for the problem at hand. Whilst agreeing that there is no one unique all-encompassing description of anything (and indeed that is part of what this processual complex ontology is suggesting), the congruence between these radically different bodies of thought, from Daoism to modern physics, adds strength and confidence in embracing this processual complex ontological stance, which we shall refer to as process complexity.

This still begs the question as to why we are of the view that surfacing and exploring issues of ontology is of such fundamental and practical importance. It is founded in the conviction that how we view the nature of things, how we view the way things stabilise or change, has a strong influence on what knowledge we deem important, and what methodologies we adopt in the world of strategy and policy. Seeing the world as complex, uncertain, emergent rather than linear, predictable, and controllable has a significant impact on theories of policy development (Room, 2011; Haynes, 2015; Boulton, 2010; Geyer and Rihani, 2010).

Complexity thinking is largely seen as an epistemological project, driven by computational modelling built on various levels of simplification (Allen and Boulton, 2011). A smaller number of authors focus on its ontological implications, e.g. Martin and Sunley (2007), Holland (2015), Bradbury (2006), Byrne and Callaghan (2014), and Boulton et al (2015). Yet our worldviews, our ontological positions, and our beliefs and biases, whether we are conscious of them or not, have huge power to shape what we see, how we interpret what we see, and what action we take. Our ontological stance is deeply interwoven with our epistemological perspective and some authors speak of onto-epistemology (Voros and Riegler, 2017). Some, indeed, speak of ethico-onto-epistemology (Barad, 2007), to emphasise, as did Paul Cilliers (Woermann & Cilliers, 2016), that in a world that cannot entirely be determined, every choice – of perspective, of action - is inevitably an issue of ethics.

It is also important to point out that not all traditions in complexity theory place so much emphasis, as did Prigogine, on "becoming," on the role of variation, and the shaping of emergent patterns through history and context. Uncertainty is both necessary and inevitable. The use of modelling in the world of complex systems can create implicit ontologies which implicitly suggest that complex systems are real things, are reified "entities" whose behaviour over time can be relatively well mapped out. Even when there is recognition that the map is not the territory, this implicit reification can imbue and shape choices of policy, action, and interpretation. Concern over this tendency to reify was the drive behind Ralph Stacey's shift from complex adaptive systems to the more processual, contextual, and granular complex responsive processes (Stacey, 2001). Complex systems can sound like a mix of artefacts: strange attractors, power laws, simple rules, fractals, sensitivity to initial conditions, and edges of chaos (Boulton, 2015:71). These artefacts are qualities of various mathematical models based on differing levels of simplification but are not necessarily or generally aspects of the "real world." This pull towards reification can lead to preferencing classification over research, design over adaptation and outcome-focus over experimentation.

Prigogine's work lends itself much more to framing complexity as a situated relational quality, seeing organisations or communities or economies as processes that are co-constituted by the people within them, impacted by their environment, and in relationship with other organisations and forms. The emphasis is more on "embracing" complexity as an inevitable and largely positive quality of the world, as a source of novelty, emergence, resilience, and change, rather than on viewing it as something to reduce, or manage, or categorise. This is not to suggest that there is complete polarisation of positions in the field of complexity, but there are without doubt differences of emphasis, and these are perhaps associated with differing implicit ontologies, not all of which have the processual flavour that is embedded within Prigogine's tradition.

With this preamble in mind, there are three aims for this paper. First, we develop the ontology of "process complexity" and show how it derives from Prigogine's original approach to complexity theory and connects to process philosophies more generally. Process ontologies emphasise the primacy of "becoming" over "being," of flow over stasis. But this focus on flow does not necessarily emphasise what is the *nature* of that flow. Process complexity adds a particular flavour to this and suggests that the flow of change can be envisaged as the emerging, stabilising and eventual dissolving of "patterns of relationships."

We show how this processual understanding of the complex world has irreversibility at its root and leads to an understanding of situations as constantly adapting, shaped but not determined by history, context-sensitive, and emergent.

Traditionally, complexity thinking works implicitly with the idea that the world can be modelled as "things" connected by "forces." By introducing a processual view, which understands "things" as interpenetrating patterns which may be fleeting or persistent, we develop a more nuanced

DOI: http://dx.doi.org/10.20377/cgn-109

and inclusive perspective of the complex world and find that the distinction between patterns and events itself dissolves.

We then explain how this extension of Prigogine-inspired complexity theory leads to the idea of ontological uncertainty.

The second aim of the paper, interwoven throughout it, is to demonstrate how process complexity resonates with the ontological stance of very different perspectives: quantum gravity, process philosophies developed during the upheaval of the Axial Age, and those of early modern process philosophers such as Whitehead, Bergson, and James. The remarkable alignment of these understandings of the way things are in the world lends depth, richness, and salience to process complexity.

The third aim of this paper is to comment, briefly, on the implications of adopting a process complexity ontology with its presumption of ontological uncertainty, for management practice and policy.

Prigogine and irreversibility: the roots of complexity thinking

When Ilya Prigogine gave his Nobel Prize acceptance speech, he said he was entranced, as a young man, by reading Henri Bergson's 'Creative Evolution' (1964) and by Bergson's question: "why does life mount the incline that matter descends?" That is to say, why does physical matter, according to the second law of thermodynamics, decay into featureless dust, whereas evolution leads, in many cases, to "transformations to higher levels of complexity" (Prigogine, 1980:xii). Prigogine's answer was to recognise that for open systems that can exchange energy and information with the wider world, entropy can decrease locally, and "structure"—patterns of increased order—can emerge. As he said in his biography "living things provided us with striking examples of systems which were highly organized and where irreversible phenomena played an essential role" (Prigogine 1977). Order emerges out of chaos (Prigogine & Stengers, 1984).

Prigogine recognised that for this to happen, there were three conditions at play. First, situations need to be open in order to exchange energy, matter, and information with their surroundings; secondly, there needs to be fluctuations, diversity, messiness; and thirdly, the diverse elements need to be interconnected reflectively, that is with the possibility of feedback (Prigogine et al, 1977:2). In this way, physics, in the form of the thermodynamics of open systems, and evolution meet. As biologist and fellow Nobel Prize winner Jacques Monod said (1972:118): "evolution in the biosphere is therefore a necessarily irreversible process, ...indeed it is legitimate to view the irreversibility of evolution as the expression of the second law [of thermodynamics] in the biosphere."

Situations that are irreversible follow a path that cannot be undone or reversed. Things happen which then create the conditions for subsequent things to happen; there is no going back. This is what physicists call path dependence[1]. If we were to film a pond, or a period in the life of a family, or a mountain river, we would know if the film were played backwards. Irreversibility can be understood as a loss of information. It happens in situations where more than one path could have occurred. In effect, the path that *did* emerge then closed down the potential for all other possible paths, and the information associated with those unrealised paths is lost. William James, writing in 1884 (Bird, 1995:274-5) puts it like this: "possibilities may be in excess of actualities...of two alternative futures.... one becomes impossible only at the very moment when the other excludes it by becoming real itself."

Stuart Kauffman (2000) names this shaping of the future, as paths are selected and others are no longer available, as non-ergodicity. Non-ergodic systems do not visit all of their possible states. He explains: "the evolution of life in our biosphere is profoundly "non-ergodic" and historical. The universe will not create all possible life forms. Non-ergodicity gives us history."

Irreversibility is at the root of complexity thinking. It is the source of path-dependence—the idea that history shapes but does not determine the future. It creates the "arrow of time." It underpins

[1] Path dependence is used within social science in various ways. We are here adopting the approach of physicists, who are referring to the way the particularity of what happens shapes and limits (but does not determine) what happens next. They speak of the system having memory.

the way the *particularities* of context, of sequence and of choice are fundamental to understanding how situations in the social and natural world evolve. Irreversibility emphasises the need for a dynamic, processual understanding of situations and draws the importance of time and duration into the heart of complexity thinking.

The core of Prigogine's contribution: how the interplay of patterns and events creates a focus on "becoming" rather than "being"

As Prigogine (1980) married the implications of evolutionary biology with the physics of open systems, he came to the recognition that we should think of the world not as stable—as "being"—but as irreversibly "becoming." Change is the norm and stability the exception. In general, there is an ongoing irreversible shift in conditions and qualities, an underlying potential for change, for evolution, for creativity and adaptability. We need to pay attention to the *dynamic* of situations. We need to follow this dynamic and trace what happens over time. It is not enough to interrogate the present; we need to explore how the past shaped the present and how the present is co-responsible for the future (Cilliers, 2001:6). That is to say, the present shapes the future, in that it constrains possible future paths, but it does not fully determine which future path will ensue. The future is a complex weave of present conditions, chance, choice, impacts from the wider context, together with a sprinkling of messiness and variation.

This process of "becoming" is not steady and incremental, but what Boulton et al (2015) have called "episodic." To call change episodic, or punctuated (Tushman & Romanelli, 1994; Gould, 1982) is to signify that, in general, development over time consists of periods that are self-regulating, wobbly but stable, interspersed with periods of change during which new factors are likely to emerge. In the quest for ontological parity, it is noteworthy that this notion of episodic change, the idea that "the door is not always open" is captured in the following extract from a commentary on the Dao de Jing, a Chinese philosophical text from the 5th century BC (Ames and Hall, 2003:83):

> "Within the rhythms of life, the swinging gateway opens, and novelty emerges spontaneously to revitalise the world. Whatever is most enduring is ultimately overtaken in the ceaseless transformation of things."

During periods of relative stability, the conditions in a given situation tend to self-organise, to settle down into identifiable patterns of relationships. For example, organisations or communities or families tend to develop relatively stable cultural norms of behaviour and routines. These are not fixed, but they can persist, and the persistence is due to the interdependent, reflective nature of relationships. As previously discussed (Boulton et al, 2015), one key insight that came out of Prigogine's work (Prigogine, Allen and Herman, 1977) is the way forms, patterns, and institutions emerge and become established. These patterns are then constantly challenged, and potentially invaded by the particular events, variations, decisions, shocks, and so on that take place in particular places at particular times, initiated both from within the situation of interest or from without.

Thus, we have an image of a world that is patterned, that is to say it has structure or form. And yet those patterns or forms are not fixed forever, but may collapse, dissolve, or shift into new patterns. Boulton et al (2015:29) describe this as "a dance between patterns and events." The "dance between patterns and events" focuses attention on the mechanisms by which complex situations change over time, and how new qualities emerge which could not have been predicted. Patterns emerge and stabilise through the interdependent reflective relationships between the constitutive elements, coupled with their openness to exchange matter and information with the wider world. Ralph Stacey (2001), in his work on complex responsive processes, is focused on this perspective, on the importance of the particularity of the details of interactions and responses in understanding how patterns of meaning or routines of behaviour are established in the social world and how change emerges.

To take an ecological example: in and around a pond, certain inter-relationships between species become established. However, over time, other species may gain traction, may "invade" these stable patterns of relationships and eventually replace them, aided perhaps through shifts of weather or changes to farming habits in the surrounding area. Equally, new species or new conditions may not make much impact and may be transitory. So, we have an interplay between "events," which might

DOI: http://dx.doi.org/10.20377/cgn-109

include new seeds dropped by birds, or a particularly wet summer which preferences some species over others, and (in this example) ecological "patterns" which are constantly flexing and shifting and may indeed shift entirely into something new and unforeseen.

This insight into the interplay between relatively stable patterns and how these are potentially invaded or destabilised by events is central to complexity theory following Prigogine. As has already been noted (Boulton et al, 2015), studying (relatively) stable patterns constitutes the primary fare of economists, marketeers, ecologists, and many systems thinkers. In contrast, "history" tends to deal with the particularity of events, conditions, and individuals. But complexity thinking, in the tradition of Prigogine, marries the two and provides us with a sophisticated and distinct theory of change (Allen, 1997:17).

In summary, the ontology underpinning complexity theory in the tradition of Prigogine is a version of process ontology, an ontology which emphasises becoming over being, which sees flow and change as the norm. Prigogine-informed complexity theory adds a particular *flavour* to this process ontology, seeing this flow as textured, as consisting of the emerging and stabilising and eventual dissolving of patterns of relationships.

How does this ontological image, emerging from the physical and natural sciences, relate to other ontologies? The focus on the way things change over time is, of course, of central concern in the field of process philosophy, both ancient and modern. Daoist, Buddhist, and pre-Socratic thinkers from India, China, and the West during the Axial Age (Puett and Gross-Loh, 2016) were thinking in this way; the substance for their deliberations was empirical in that it derived from lived experience. Daoist thought in particular captures many of the insights from complexity theory, for example, the episodic nature of change, the emergence of novelty[2], and in notions of pattern formation[3].

Early modern process philosophers, such as William James, Henri Bergson and Alfred North Whitehead were substantially motivated by the processual implications of evolution, as of course was Prigogine (Seibt, 2020).

Are processes and events really different in kind? From Prigogine to process complexity.

The "restricted complexity" (Morin, 2008) consistent with the computational modelling of complex systems can convey an idea that the world is made up of concrete "things" or elements connected by forces, albeit nonlinear forces. But things are made up of molecules and molecules are made up of atoms which share electrons. These electrons can be considered as waves or processes as much as particles. In the end, the "thingness" of things vanishes into interpenetrating fields of energy and probability. The notion of what is a "thing" and what is a "force" becomes blurred. We can instead envisage interactions akin to the way ripples interact on the ocean. Ripples are identifiable entities, albeit temporary and with ill-defined boundaries. They impact each other, may merge, may separate again, and may disappear. We would not describe their interactions and impacts as caused by forces; they interact due to their own characteristics (of speed, amplitude, temperature), due to their unique nature, at a particular place and time. This is a so-called "field-theoretic"[4] approach.

Thus, the description of the shaping of the future as a "dance between patterns and events" can be extended and reframed as a dance between long patterns and short patterns, or indeed between long events and short events. In this appeal to field theory, we move beyond positing "patterns" and "events" as distinguishable entities, as different in kind. We then arrive at a description of a processual ontology understood as patterns or processes, longer or shorter, larger or smaller, which are interpenetrating, intersecting, emerging, and dissolving. To illustrate with an example, think of a new

[2] For example, "It is the under-determined nature of way-making that makes it inexhaustibly capacious; and gives the quite appropriate impression that nothing is perfect or complete." (Ames & Hall, 2003:83)

[3] For example, "Integrity is something becoming whole in its co-creative relationships with other things. Integrity is consummatory (is the inevitable consequence of) relatedness." (Ames & Hall, 2003:16)

[4] Field theory is a fundamental approach within physics, underpinning electromagnetism, sound, quantum theory, relativity, and so on.

DOI: http://dx.doi.org/10.20377/cgn-109

leader. We can envisage this leader as an event which happens to the organisation. But in actuality, that leader is part of other social patternings—family, community, peer group, and so on. Should the leader be construed an event acting on the organisation or is the leader better thought of as part of pre-existing, intersecting social patterns that engage with the organisational patterning in a way that changes and shifts and reshifts all of them?

This processual view of complexity, this image of ripples intersecting on the ocean, has remarkable similarities with sciences and philosophies from many different traditions.

For instance, from the field of quantum gravity, Rovelli explains that "the world is made up of events not things. Even the things that are most "thing-like" are nothing more than *long events*. The world is not so much made of stones as of fleeting sounds or waves moving through the sea" (Rovelli, 2018:85-88).

In similar vein, Ames and Hall (2003:13), in reflecting on Daoist ontology, argue that "particular things are in fact processual events and are thus *intrinsically* related to other things that provide them context... these processual events are porous, flowing into each other in the ongoing transformation we call experience."

This allowance of the interpenetration of "things" within complexity theory, an approach that physicists would recognise from field theories, provides a richer more subtle ontology than the implicit notion of "things connected by forces." This paves the way for a richer understanding of the characteristics and qualities of the ever-emerging complex world. We can call this *process complexity*. What gives it ontological strength is that process complexity resonates strongly with such different disciplines as quantum gravity and process philosophy, both ancient and modern. More recently, those working with process theories of organisation have reached not dissimilar understandings (e.g. Tsoukas, 2016 and 2006; Hernes, 2014; Chia, 1998).

Ontological uncertainty

This paper is focused on the ontology of process complexity, an extended version of complexity theory building on the work of Prigogine and its basis in irreversibility. One aspect of this ontology is the notion of ontological uncertainty: that the future is not knowable in its entirety because there is no one future.

Complexity theory emphasises that when new qualities emerge, there is no way of knowing for sure *when* this will happen and *what* these new features will be. New variables may appear which have not before been considered or seen. It is not that we know nothing; there may be signs of increasing instability or emerging newness, there may be indications of likely future states. But there remains a level of uncertainty that cannot be overcome.

The question is, at times of emergence, are we dealing with the issue that the situation is too *complicated* for the modeller to both know everything pertinent and be able to include in a model? This is epistemological uncertainty. Or are we dealing with something more fundamental, that even La Place's daemon sitting out there in the heavens could not know (Morin, 2008), because uncertainty is woven into the very fabric of the universe. This is ontological uncertainty; what will happen at points of emergence *cannot* be known in its entirety, although neither is it random. William James (Bird, 1997:274-5) understood this point. He says there is no "one unbending unit of fact." Things "may really in themselves be ambiguous," not just to our understanding but because reality can have in and of itself an ambiguous quality.

The notion of ontological uncertainty sits in contrast to the assertion that the universe is Platonic, i.e., that it could *in principle* be described entirely by mathematics. If that were the case, then in effect everything, including evolution, would be pre-determined and unfold towards a pre-existent future. It is clear that the deterministic laws of physics take us a very long way towards understanding both the very big (for example the gravitational redshift following Einstein's relativity was measured decades after it was predicted) and the very small (as, for example, the prediction of the Higgs boson). But, as Leibniz pointed out to Newton (Alexander, 1956), Newton's laws have nothing to say about the *particular* structure of, say, our solar system or our galaxy. If the universe is entirely to be understood through mathematics, it would, in principle be entirely predictable if the initial conditions were known.

DOI: http://dx.doi.org/10.20377/cgn-109

To quote William James, what had been "laid down" would "absolutely appoint and decree" the future, which would have "no ambiguous possibilities hidden within its womb" and would operate like an "iron block" (Bird, 1995:274-5). Thus emergence, evolution, surprise, adaptation or indeed, for living beings, choice or freewill would either not exist or be *accidental*. Lee Smolin (Smolin 1997:17) points out "the properties of things are not fixed absolutely, they arise from the interactions and relationships among the things in the world." The universe evolves to have *particularity*—of galaxies and their solar systems, and their actual unique planets.

The important point that we are bringing out through this foray into cosmology is that we cannot understand the *particularity* of where planets and galaxies are, and what forms they have taken, just through recourse to fixed natural laws. Uncertainty and indeterminism happen at this level too. As Prigogine (1980:vii) and Lee Smolin and Brian Swimme (2011) all suggest, the evolutionary principle seems to operate in the universe as a whole not just in the living world. "The fact that we live in a universe with structures at so many scales is so commonplace, so manifest, that it is easy to miss its significance" (Smolin 1997:204).

This worldview, congruent with complexity thinking, emphasises that uncertainty and messiness are *necessary* conditions for emergence, irreversibility, surprise, novelty, and change. And this ontological uncertainty, this indeterminism, also is what gives space for mystery, ambiguity, and paradox. And even at the level of the universe, there seems to be an intrinsic ontological paradox or ambiguity in its very fabric; it is an inescapable and necessary part of how things are.

Ontological uncertainty has huge implications for how we consider "reality," what we regard as knowledge and how we seek it. Kauffman (2008:231) said:

> "In this [complexity-framed] ...scientific worldview... we live in an emergent universe of ceaseless creativity in which life, agency, meaning, consciousness and ethics have emerged. Our entire historical development as a species, our diverse cultures, and our embedded historicity, have been self-consistent, co-constructing, evolving, emergent and unpredictable. Our histories, inventions, ideas and actions are also parts of the creative universe."

Discussion

We can of course, reach processual ontologies and uncertainty via routes that start in sociology or in philosophy. Why, then, is it useful to start with a theory from the natural sciences and reach a similar point from that direction? In part, this focus on ontological uncertainty counters the not uncommon view that, if we have detailed enough experiments or models or methodologies, we will overcome and "manage" complexity and find the simple and deterministic mechanisms hidden in its depths. To be able to counter this argument from the same stable from which it emerged, that is from the physical sciences, confers a particular type of power in discourse. This is not to ignore the dangers of taking physics theories and applying them to the social world unquestioningly, as happened to Newton's theories during the Enlightenment and to equilibrium thermodynamics and its assimilation into classical economics[5]. We are still reaping the outcomes of the assumptions that organisations behave like machines, or economic systems tend toward a natural equilibrium.

But if we can show that the science of open systems is remarkably congruent with process philosophies both ancient and modern, then does that congruence not add weight to both? Can we not feel more confident to explore concepts from complexity thinking and "try them on for size," see if they are any help in guiding practices in management and policy? Seeing how the science of complexity, particularly in its processual form, reaches a similar place from a starting point emerging from the natural sciences seems a valuable contribution. It can strengthen our confidence to adopt these approaches to working in the complex world. It moves the ontological quest from a choice driven by personal preference to one triangulated between science, philosophy, and empiricism.

[5] Walras (1874) famously said: "this pure theory of economics is a science which resembles the physico-mathematical sciences in every respect."

DOI: http://dx.doi.org/10.20377/cgn-109

Implications

We have written previously about the implications of complexity theory for policy (Boulton, 2010), emphasising the need for systemic adaptive policy making which explicitly weaves together the economic, the environmental, the social, and the political, and allows for the unanticipated, for learning and for regrouping in light of unexpected outcomes or unforeseen events. Policies need to be both more agile to respond to the unexpected and allow for a degree of customisation to meet the particularities of context and history. Whilst the broad purpose and key principles of, say, education policy may be overarching, the way best to enact it could well be to allow local schools or regions to respond more adeptly to their own particular demographies, resources, and histories. The need for agility, adaptability, and contextuality in policy making is well-recognised (e.g. Room, 2011).

Further to this understanding, the processual view of complexity emphasises how the complex world is interwoven through to the smallest scale, the tiniest of ripples, the most fleeting of interactions. Thus, in thinking systemically about policy, it is not sufficient to develop separate policies and then connect them or negotiate between them. Rather, policy and management processes must emerge from the detailed interweaving of these factors from the ground up. For example, when buying a car, the person does not separate the economic (what does it cost) from the social (this car suits the image I want to convey) from the political (should I even be buying a car in this age of global warming). These factors interweave in a way that is hard to deconstruct and together result in a decision. Would we not do better, for example, to develop socio-environmental, rather than primarily environmental understandings and policies to tackle climate change (Biggs et al, 2021)? If we put into battle economic arguments against social or environmental ones (for example in decisions to build a new airport) is it not often the case that the economic argument wins? There are many local examples as to where housing policy, infrastructure development, attention to the environment, and local commerce are not developed systemically and integratively and where each case for, say, new housing, is argued separately. A process complexity perspective supports the position that it is not sufficient to try and *couple* policies or engage in debates *between* policies; rather, policy-making should be systemic from its inception.

The embracing of ontological uncertainty emphasises that the search for the right method arrived at through objective and rational analysis is largely futile. Ontological uncertainty requires us to use a multiplicity of methods and involve a multiplicity of diverse participants to home in on what is happening and what might be useful in response. Heron and Reason (1997) call this "critical subjectivity." Our epistemology is necessarily subjective, imperfect, and contextual when there is no possibility of a defined objective reality. It emphasises the inevitability of ambiguity and paradox, the need to wrestle with, for example, balancing short term goals with long term aims, or working with the tensions between freedom and responsibility or between innovation and efficiency (Mowles, 2015). It underlines that there is no perfect political ideology, or universally appropriate methods of management or change.

We are not of course arguing that the recognition of paradox is unique to complexity, but its derivation from the world of science may be helpful in discouraging managers from searching for the perfect answer and help to shift the balance between analysing and experimenting.

The implication of embracing ontological uncertainty is also to place centrally the issue of ethics. What we chose to focus on, what we regard as important information, or desired outcomes or appropriate methods is inevitably an ethical choice. If the world is not objectively real, then our choices, even when working "scientifically," will always be influenced by what we and others value, what we see as relevant and appropriate (Woermann & Cilliers, 2016). Ontological uncertainty underlines the importance of surfacing biases, beliefs and predilections in a world that is inevitably incomplete, subjective, and subject to the emergence of the radically new.

There are further implications for practice, and these relate to emphasis on the processual, on the way the past shapes the present and the present shapes the future. For example, by making the effort to investigate the history of an organisation or a region, we can judge the strength and longevity

DOI: http://dx.doi.org/10.20377/cgn-109

of cultural patterns to inform our strategies[6]. Or, through positing that we can understand situations as emerging, stabilising, and dissolving patterns, we can consider which of those patterns we would aim to *strengthen,* e.g., through building relationships, sharing resources, and weaving common intentions, and which we would aim to *disrupt,* e.g., through "nudging," or activism, or supporting outsider views, switching resources, or piloting alternatives. Theories of systemic change can sometimes place more attention on what needs to be strengthened than on what needs to be disrupted, unfrozen, or indeed encouraged to collapse.

One important practice in seeking to engender change is to be alert to emerging "weak signals" of change, even when these are small and subjective (Scharmer & Senge, 2016). Daoism expresses a similar interest in the way change starts with the small and seemingly insignificant. Jullien (2004:69) notes that, for Daoists, "the skill [of the leader] lies in the earliest possible detection of the slightest tendencies that may develop. By spotting these almost before they have begun, before they have had time to emerge and manifest their effects, the leader will be in a position to foresee where they will lead." Recent discussions with Shaw (2021) and Melo (2020) demonstrate that there are those working with ideas akin to processual complexity who see this skill in spotting and responding to early signs of emerging change as one of the most important aspects of engendering change.

Finally, even contemplating a complexity mindset may engender a sense of humility, a greater willingness to experiment. It may erode unfounded confidence and certainty and suggest a different balance between learning through doing and planning through analysis. Embracing a complexity mindset has the potential to open up new questions and new perspectives at the same time as constraining the desire for definitive answers.

Conclusion

First, we have developed process complexity as an extension to the "things connected by forces" version of complexity theory that emerges from mathematical modelling and scientific rationalism. We have built on the work of Prigogine, whose starting point was irreversibility and the thermodynamics of open systems.

We then explored how this extension of complexity theory leads to the idea of ontological uncertainty and its connection to emergence.

We have explored how process complexity resonates with the ontological stances of such very different perspectives as those from quantum gravity, Daoism, cosmologists like Smolin and Swimme, and those of early modern process philosophers such as Whitehead, Bergson, and James. This congruence seems remarkable and lends conviction and richness to this ontological quest for understanding the world as complexity in process.

This thinking leads on to questions of practice for shaping strategies and policies, for understanding change and for considering the implications for leadership in a complex, deeply interconnected and interdependent world.

References

Alexander, H.G. (1956) *The Leibniz-Clarke correspondence*. Manchester University Press

Allen, P. (1997) *Cities and Regions as Self-organising Systems*. Gordon and Breach Science Publishers.

Allen, P & Boulton, J. (2011) Complexity and Limits to Knowledge: the importance of Uncertainty. In Allen, P., Maquire, S., & McKelvey, B. (Eds), *The Sage Handbook of Complexity and Management*. Sage

Ames, R.T. and Hall, D.L. (2003) *Dao de Jing: A philosophical translation*. Ballantine Books

Barad, K. (2007) *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press

Bergson, H. (1964) *Creative Evolution*. Macmillan and Co Ltd (Original work published in 1911)

Bird, G.H. (1995) *William James: Selected Writings*. Everyman

Biggs, R, et al (2021) *The Routledge Handbook of Research Methods for Social-Ecological Systems*. Routledge.

Boulton, J. (2010) Complexity Theory and Implications for Policy Development. Emergence: Complexity and Organisation 12(2): 31-41.

[6] See Boulton et al (2015: 196-8) for further exposition.

DOI: http://dx.doi.org/10.20377/cgn-109

Boulton, J., Allen, P.M., & Bowman, C. (2015) *Embracing Complexity*. Oxford University Press

Bradbury, R. (2006) Towards a New Ontology of Complexity Science. In Perez, P. & Batten, D. *Complex Science for a Complex World: Exploring Human Ecosystems with Agents*. ANU Press, pp. 21–26. *JSTOR*, www.jstor.org/stable/j.ctt2jbhz2.8.

Byrne, D, & Callaghan, G. (2014) *Complexity Theory and the Social Sciences*. Routledge

Chia R. (1998) From complexity science to complex thinking: organization as simple location. *Organization* 5(3): 341–370.

Geyer, R. & Rihani, S. (2012) *Complexity and Public Policy: a new approach to 21st century politics, policy and society*. Taylor and Francis

Gould, S. J. (1982) Punctuated Equilibrium—A Different Way of Seeing. *New Scientist* 94 (Apr. 15): 137-139

Haynes, P. (2015) *Managing Complexity in the Public Services*. Routledge

Hernes, T. (2014) *A Process Theory of Organisations*. Oxford University Press

Heron, J. & Reason, P. (1997) A Participative Inquiry Paradigm. *Qualitative Inquiry*, 3 (3)

Holland, D. (2015) Complex Realism, Applied Social Science and Post-disciplinarity: A Critical Assessment of the Work of David Byrne. *Journal of Critical Realism* 13 (5) pp 534-554. https://doi.org/10.1179/1476743014Z.00000000042

Jackson, M. (2019) *Critical Systems Thinking and the Management of Complexity*. Wiley

Jullien, F. (2004) *A Treatise on Efficacy*. University of Hawaii Press

Kauffman, S. (2008) *Reinventing the Sacred*. Basic Books

Kauffman, S. (2000) *Investigations*. Oxford University Press

Martin, R. & Sunley, P. (2007) Complexity Thinking and Evolutionary Economic Geography. *Journal of Economic Geography* vol 7(5), pp 573-601. Oxford University Press

Melo, A. (2020) *Performing Complexity: Building Foundations for the Practice of Complex Thinking*. Springer.

Monod, J. (1972) *Chance and Necessity*. William Collins Sons and Co Ltd

Morgan, G. (1986) *Images of Organisation*. SAGE

Morin, E. (2008) *On Complexity*. Hampton Press.

Mowles, C. (2015) *Managing Uncertainty*. Routledge

Prigogine, I. (1977) *Biographical notes on gaining the Nobel Prize*. https://www.nobelprize.org/prizes/chemistry/1977/prigogine/biographical/

Prigogine, I. (1980) *From Being to Becoming: Time and Complexity in the Physical Sciences*. W H Freeman and Company

Prigogine, I. & Stengers, I. (1984) *Order out of Chaos*. Bantam

Prigogine, I., Allen, P.M., & Herman, R. (1977) Long term trends and the evolution of complexity. In Laszlo, E., & Bierman, J. (Eds.) *Goals in a Global Community*. Pergamon Press

Puett, M., & Gross-Loh, C. (2016) *The Path*. Penguin Books

Rescher, N. (2000) *Process Philosophy: A survey of basic issues*. University of Pittsburgh Press.

Romanelli, E. & Tushman, M. (1994) Organizational Transformation as Punctuated Equilibrium. The Academy of Management Journal. 37 (5), pp. 1141-1166

Room, G. (2011) *Complexity, Institutions and Public Policy*. Edward Elgar

Rovelli, C. (2018) *The Order of Time*. Allen Lane

Scharmer, O. & Senge, P. (2016) *Theory U*. Berrett-Koehler Publishers

Seibt, J. (2020) Process Philosophy. In Zalta, E.N. (Ed.) *The Stanford Encyclopaedia of Philosophy* (*Summer 2020 Edition*). <https://plato.stanford.edu/archives/sum2020/entries/process-philosophy/>.

Shaw, P. (2021) Private communication

Smolin, L. (1997) *The Life of the Cosmos*. Oxford University Press

Swimme, B., & Tucker, M.E. (2011) *Journey of the Universe*. Yale University Press

Stacey, R. (2001) *Complex Responsive Processes in Organizations:* Routledge

Tsoukas H. (2006) *Complex Knowledge: Studies in Organizational Epistemology*. Oxford University, Press: Oxford.

Tsoukas, H. (2016) Don't Simplify, Complexify: From Disjunctive to Conjunctive Theorizing in Organization and Management Studies. *Journal of Management Studies* 54 (2)

Voros, S. & Riegler, A (2010) A Plea for not Watering Down the Unseemly: Reconsidering Francisco Varela's Contribution to Science. *Constructivist Foundations* 13(1): 1-10. https://constructivist.info/13/1/001.editorial

Woermann, M. & Cilliers, P. (2016) The Ethics of Complexity and the Complexity of Ethics, in *Critical Complexity: Collected Essays*. De Gruyter